MASTER

Minimum temperatures under cloches

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During the Spring of 1960 a series of observations was made of minimum temperatures under cloches at Westbury-on-Trym, Bristol, with the following objects:-

(i) to determine the degree of protection provided by the cloches

(ii) to determine approximately the pattern of temperature distribution beneath the cloches, and

(iii) to examine the relationship between the protection achieved and certain meteorological parameters.

The cloches used were the standard "Growers Barn" type and they were set up over short grass, a line of nine of them running approximately East-West with the two ends blanked off by plain glass. The thermometers were installed in the central cloche. Four were arranged with bulbs touching the centre of the glass of each side- and roof-piece. The other three were mounted on improvised wooden mounts in the centre of the cloche to give some indication of the vertical distribution of temperature beneath the ridge. Figure 1 shows the arrangement and numbering of the various thermometer sites. The grass minimum thermometer on the standard meteorological plot served as a control and as far as possible the covered area was kept identical with the standard plot. The grass was cut four times and, to avoid marked differences in soil moisture, the cloches were moved on to fresh ground once. Observations started on March 9 and ceased on May 9.

The protection afforded by cloches is greatest on radiation nights and the data were therefore grouped into those recorded after radiation nights and those recorded after non-radiation nights. A night was classified as a radiation night when it was clear that the following conditions had been satisfied for several hours:

Wind not greater than Beaufort Force 2

Not more than 4/8 low cloud

No precipitation

In general there was no difficulty in classifying the nights from published Daily Weather Reports, but a few doubtful cases required a study of the hourly observations from Filton, some 3 miles from Westbury-on-Trym. During the period of investigation there were 27 radiation nights and 30 non-radiation nights.

All temperatures were expressed as $T_C - T_G$ where T_C is the minimum temperature at the appropriate cloche site and T_G is the grass minimum. The mean value of $T_C - T_G$ are given in Table I.

Table I. Average temperatures under cloches, expressed as $T_c - T_G$

Line I Occasions when grass minimum $\leq 32°F$

II Radiation nights

III Non-radiation nights

	No. of observations	Thermometer site number: 1	2	3	4	5	6	7
I	8	+2.3**	+0.8	+1.1**	+1.8**	+3.9**	+3.0**	+3.0**
II	27	+2.2**	+0.4*	+0.9**	+1.7**	+3.8**	+2.7**	+2.8**
III	30	+0.5**	+0.1	0	-0.4*	+0.5*	-0.5*	+0.7**

* indicated significance at the .05 level and ** at the .01 level

The values in lines I and II show that there was some protection at all measuring points on radiation nights, but it was fairly small on the roofs (sites 2, 3). It was somewhat greater on the (approximately) vertical walls of the cloche (sites 1,4), and the maximum protection was recorded in the middle of the cloches (sites 5, 6, 7), particularly near the ground (site 5). Considering all radiation nights (line II) the average protection near the ground in the middle of the cloche was nearly 4°F and this was reduced to somewhat less than 3°F high in the cloche. Along the side walls the protection was $1\frac{1}{2}°-2\frac{1}{2}°$F but under the centre of the roof pieces it fell to less than 1°F. All of the deviations in line II are significant, all but one at the .01 level. The greatest protection was observed on the morning of April 20, when the following values were recorded:-

Table II. Temperatures under cloches on April 20, 1960 expressed as $T_C - T_G$

	Thermometer site number						
	1	2	3	4	5	6	7
	+3.1	+2.1	+2.0	+2.1	+5.2	+4.2	+4.0

The values in Table I and II confirm the generally accepted view of the effect of cloches or other protective coverings, viz., that the cloche becomes the effective radiating surface and that the glass is at least partly opaque to the long-wave radiation from the earth or plants beneath it. Geiger (1) gives a diagram of isotherms about a frost protection shelter used in the Gumpoldskirchen area, based on observations by Schmidt (2). The isotherms suggest that at a position roughly corresponding with site 5 the protection amount to some 3°C ($5\frac{1}{2}°$F).

The values for non-radiation nights in line III suggest that there is no worth-while protection on these nights. Some values are negative and any statistical significance is probably due to the characteristics of the individual cloches and not to any general property of cloches.

The difference in the degree of protection afforded by the cloches on the various radiation nights is clearly dependent mainly on meteorological factors. Two of the most important of these are:-

(i) The amount of sunshine during the previous day.

(ii) The strength of the inversion in the lowest few feet of the atmosphere. This can be approximately represented by the difference between screen minimum and grass minimum temperatures ($T_N - T_G$). When $T_N - T_G$ is small, the night is probably not a radiation night; when it is large, the night is still and clear. On the 27 radiation nights studied, $T_N - T_G$ varied from 3° to 10°F.

As a measure of the degree of protection the value $T_C - T_G$ at Site 5 was used. The various statistical parameters between sunshine, strength of inversion and protection are given in Table III.

Table III. Correlation and regression coefficients

1 = Protection, $(T_C - T_G)$ °F

2 = Strength of inversion $(T_N - T_G)$ °F

3 = Sunshine on previous day at Filton, hours

r	r_{12}	r_{13}	r_{23}	$r_{12.3}$	$r_{13.2}$
	+.70**	+.46*	+.23	+.69**	+.44**
b	b_{12}	b_{13}	-	$b_{12.3}$	$b_{13.2}$
	+.40**	+.14**		+.37**	+.09**
S.E. of b	.09	.05	-	.08	.04

These values indicate that there is a closer association between protection and strength of inversion than between protection and sunshine. Fig.2 shows the plotted values of protection (P) against strength of inversion (I) and the line of the regression equations:

$$P = .40\ I + 1.03 \qquad (i)$$

Fig.3 shows the plotted values of protection (P) against sunshine (S) and the greater scatter of observations is apparent. This is also seen from ratios b/S.E. which can be derived from Table III. The regression equation is:

$$P = .14\ S + 3.02 \qquad (ii)$$

Using partial regressions, we get the following equation:

$$P = .37\ I + .09S + .74 \qquad (iii)$$

Fig.4 shows the relation between the observed and computed values of P using equation (iii). On this diagram, as on Figures 2 and 3, the plotting for the first three radiation nights are shown by a cross. These were isolated radiation nights and their deviations from the regression lines suggest that the relationships found are more typical of anticyclonic spells than of isolated radiation nights. A further experiment is planned with cloches over bare soil.

Summary

On radiation nights, standard "Growers Barn" cloches gave an average protection of nearly 4°F close to the ground near the centre of the cloches over short grass; on individual nights this exceeded 5°F. The protection decreased upwards and outwards (towards the glass) and was least on the roof. An estimate of the protection given may be obtained if the following are known: sunshine of the previous day, grass minimum temperature and screen minimum

References

1. Geiger, R. The climate near the ground. Cambridge, Mass. 1959.

2. Schmidt, Wilh., Met. Feldversuche u. Frostabwehrmittel. Anhang Jahrb. d. Zentralanst. f. Met. Wien 1927, Wien 1929.

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G.1726/1/61/ES/80.

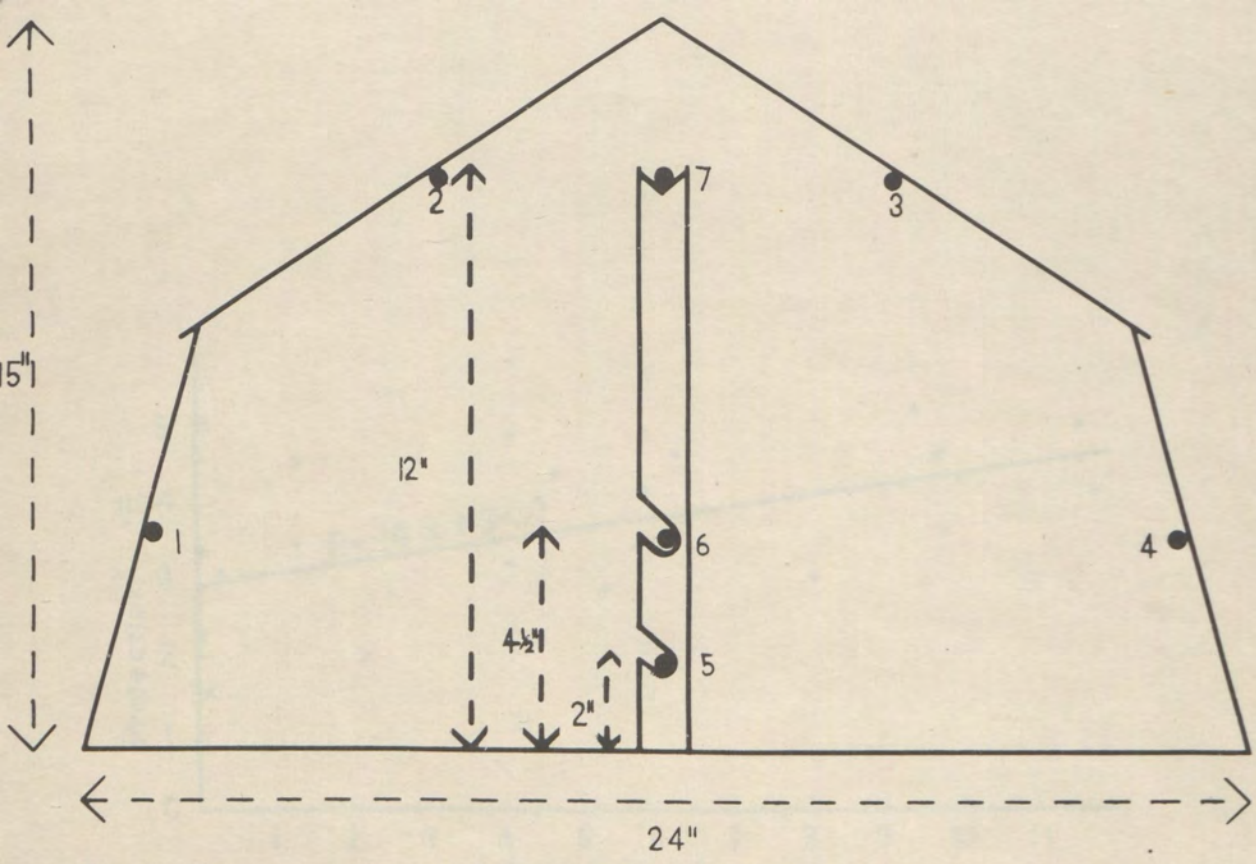

Fig.1. Cross section of central cloche to show position and numbering of thermometer sites

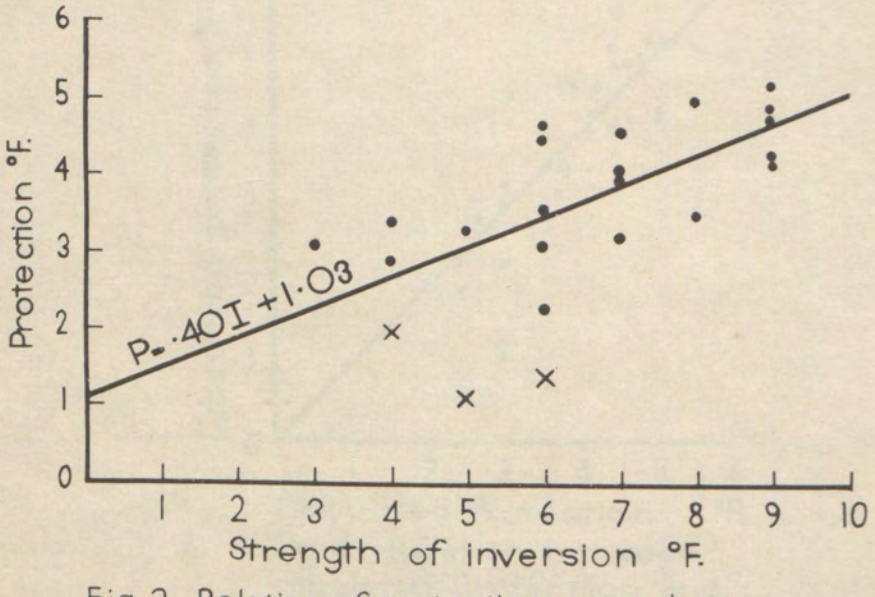

Fig.2. Relation of protection on radiation nights to strength of inversion. (Tn-Tg).

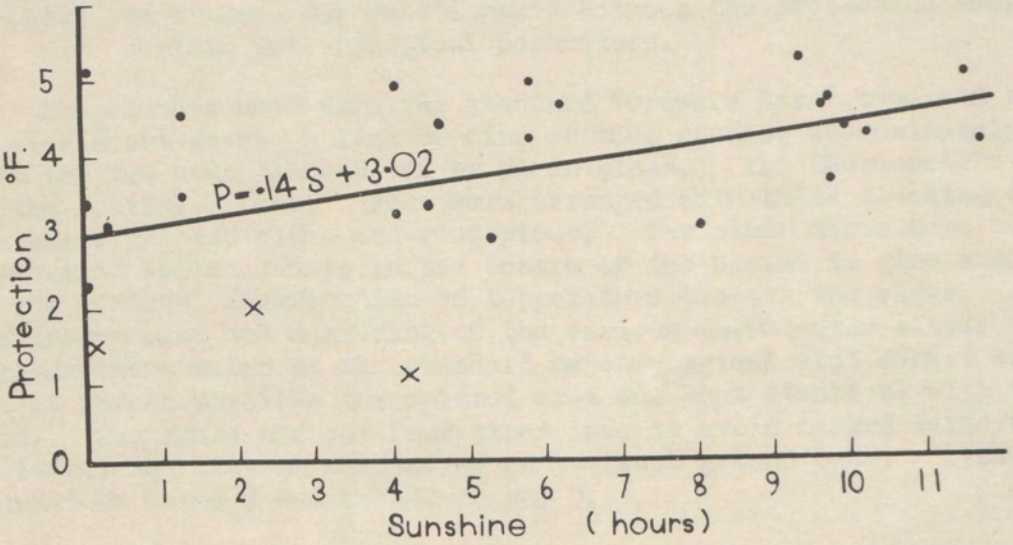

Fig.3. Relation of protection on radiation nights to previous day's sunshine

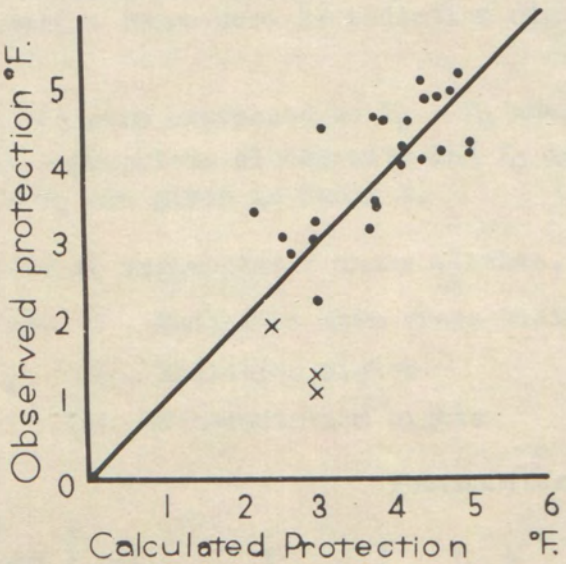

Fig 4. Relation between calculated protection and observed protection